

1 Fiber optic hydrophone systems are under development and it is  
2 desirable to provide shape sensing that is compatible and that  
3 reduces the cost of the shape sensing.

4 An alternative way to determine array shape is by curvature  
5 sensors and either roll or twist sensors. Roll sensors have the  
6 advantage of sensing an absolute parameter at each point  
7 measured.

#### 8 SUMMARY OF THE INVENTION

9 Accordingly, it is an object of the present invention to  
10 provide a fiber optic sensing device which may be used as a  
11 fiber optic roll sensor or as a fiber optic pitch sensor.

12 It is yet another object of the present invention to  
13 provide a fiber optic sensing device which may be used as a  
14 fiber optic roll sensor or as a fiber optic pitch sensor in a  
15 towed array.

16 It is a further object of the present invention to provide  
17 a sensing device as above which is simple and relatively  
18 inexpensive.

19 The foregoing objects are attained by the sensing device of  
20 the present invention.

21 In accordance with the present invention, a sensing device  
22 is provided which may be used as a roll sensor and/or as a pitch  
23 sensor. The sensing device broadly comprises at least one  
24 optical fiber supported in a structure, a movable mass supported

1 within the structure, and means for detecting changes in tension  
2 in the at least one optical fiber due to movement of the movable  
3 mass. The only deformable structure in the sensing device of  
4 the present invention is the optical fiber(s), thereby  
5 maximizing sensitivity.

6 Other details of the sensing device of the present  
7 invention, as well as other objects and advantages attendant  
8 thereto, are set forth in the following detailed description and  
9 the accompanying drawings wherein like reference numerals depict  
10 like elements.

#### 11 BRIEF DESCRIPTION OF THE DRAWINGS

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13 FIG. 1 is a sectional view of a sensing device in  
14 accordance with the present invention;

15  
16 FIG. 2 is a sectional view of the sensing device of the  
present invention taken along lines 2 - 2 in FIG. 1;

17  
18 FIG. 3 shows an alternative embodiment of the sensing  
device of the present invention; and

19  
20 FIG. 4 shows yet another alternative embodiment of the  
sensing device of the present invention.

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#### 22 BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

23 A first embodiment of the sensing device of the present  
24 invention is shown in FIGS. 1 and 2. As shown therein, the

1 sensing device 10 has a plurality of optical fibers 12 strung  
2 under tension inside a cage 14.

3 The side wall 17 of the cage 14 has a plurality of notches  
4 15. The notches 15 serve two purposes. First, they keep the  
5 optical fibers 12 radially distributed in an even manner around  
6 a mass 16. Second, the notches 15 provide a space so that the  
7 optical fibers 12 are not crushed between the cage 14 and the  
8 mass 16 during shock events. Instead, the outside surface 40 of  
9 the mass 16 contacts the inside surface 41 of the cage 14,  
10 limiting the travel without crushing any of the optical fibers  
11 12.

12 While FIG. 2 shows the notches 15 in the side wall of the  
13 cage 14, they could alternatively be located in the mass 16,  
14 instead of the cage, as shown in FIG. 3.

15 As can be seen from FIGS. 1 and 2, the mass 16 is suspended  
16 within a portion 19 of the cage 14 by the surrounding optical  
17 fibers 12. The mass 16 is initially in contact with all of the  
18 optical fibers 12. This places each of the optical fibers 12 in  
19 a prestrained state. If the device 10 is disposed vertically,  
20 all of the optical fibers 12 have the same prestrain. When the  
21 device 10 is disposed horizontally and rolls, the relationship  
22 of the optical fibers 12 and the mass 16 to the axis of the  
23 gravitational field changes. The optical fiber or fibers 12 on  
24 the bottom bear more weight and are strained greater than their